How Can EESS Missions Prevent Interference to The DSN?

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Why Is X-Band Downlink Protection critical to the DSN

- **X-band is DSN's life line**
  - X-Band is used by every deep space mission, NASA and worldwide, as either the only or the primary downlink at present and in the foreseeable future. It has only 50 MHz.
- **Very weak spacecraft signals**
  - DSN must use very large antennas (34 and 70 meter diameter) and very-low-temperature receivers (around 20 Kelvin) to receive signals (as low as –240 dB W/m^2) transmitted from spacecraft from very far away (Voyage 1, for example, is at >85 AU).
- **Radio science experiments**
  - CW signals received from a planetary mission are also used to observe the physical characteristics of the media in the path of propagation, such as rings of Saturn and atmosphere around a planet. Any interference near the receiver noise floor is a contamination to the experiment.
- **Data criticality**
  - Deep space missions often transmit date taken at planetary encounters or other unique events that NASA can not afford to lose.

The ITU Recommended Protection Criteria

- **The ITU Radio-communication Bureau has published the X-Band protection criteria for Space Research Service, deep space, in ITU-R Recommendation SA.1157, as follows:**
  - **The interference Power Spectral Density (PSD) limit is - 220 dB W/Hz and the Power Flux Density (PFD) limit is – 255 dB (W/m^2/Hz),**
    - **The PSD limit is 6 dB lower than the receiver system temperature (No), and would raise it by 1 dB.**
    - **The corresponding PFD assumes tracking by a 70-meter antenna.**
  - **That the above limits should not be exceeded more than 0.001% of time.**
    - **SA.1157 specifies that this allowance is for interference propagated trans-horizon in adverse weather. Interference from man-made satellites must be insignificant compared to this level.**

Two EESS Examples: TERRA and AQUA

- **TERRA (2000) did not implement any filter for its direct broadcast mode. As a result, operational coordination between TERRA and the DSN was necessary.**
  - **Significant initial effort in studying, testing, and coordination planning.**
  - **Significant continuing effort in operational coordination involving predictions, schedules, and approvals of waivers**
  - **Significant loss of TERRA transmission time and freedom**
- **AQUA (2002) implemented a filter on board specifically to protect the DSN. It is operating the direct broadcast mode freely without need for coordination.**
  - **AQUA made DSN protection an explicit requirement in the Project requirement document (RF ICD). The contractor(TRW) responded explicitly in the design document and test report.**
- **The following two charts show the spectrum roll-off relative to the DSN protection limit in the 8400-8450 MHz band. TERRA violated the limit. AQUA satisfied it.**

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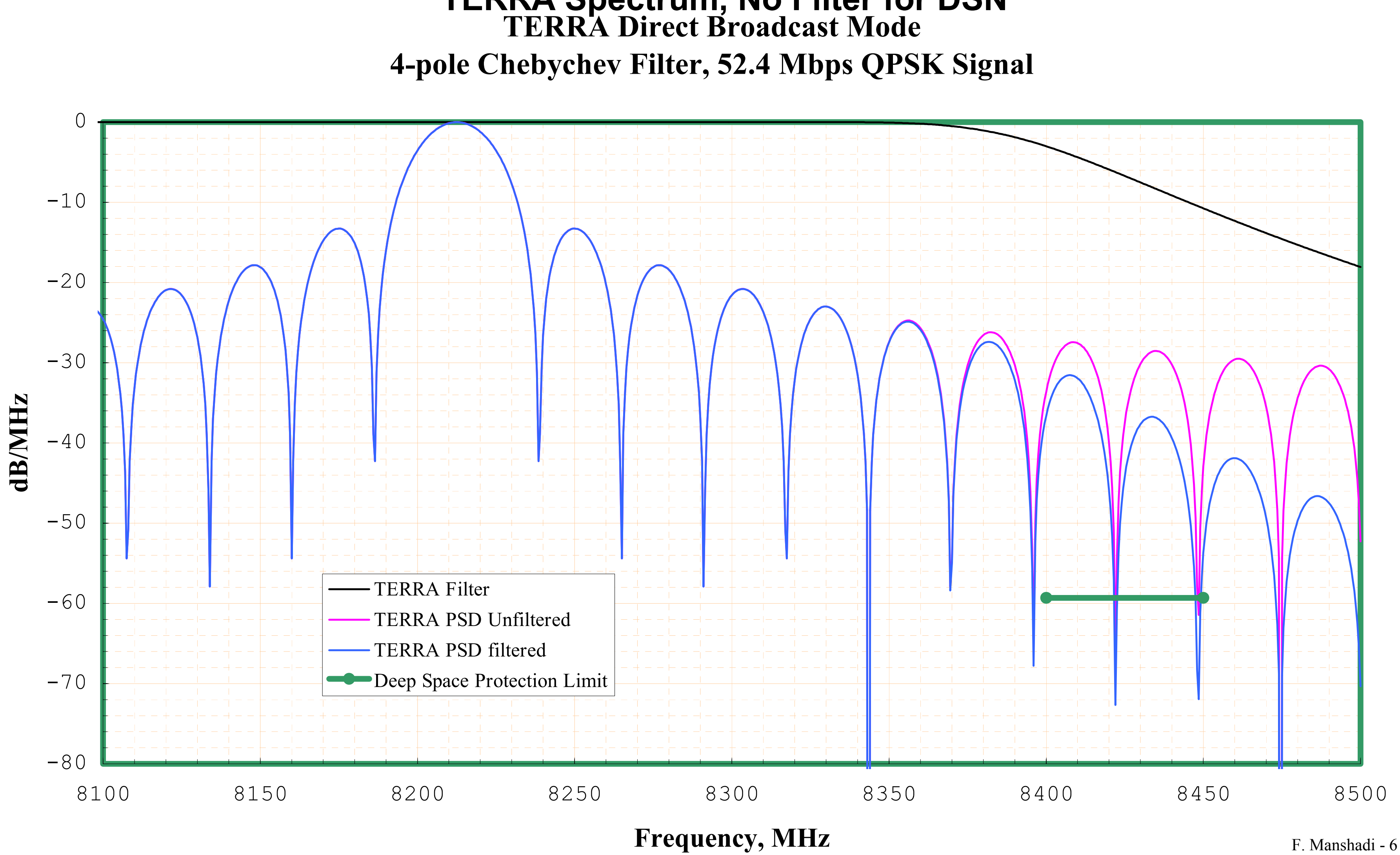
TERRA Spectrum, No Filter for DSN

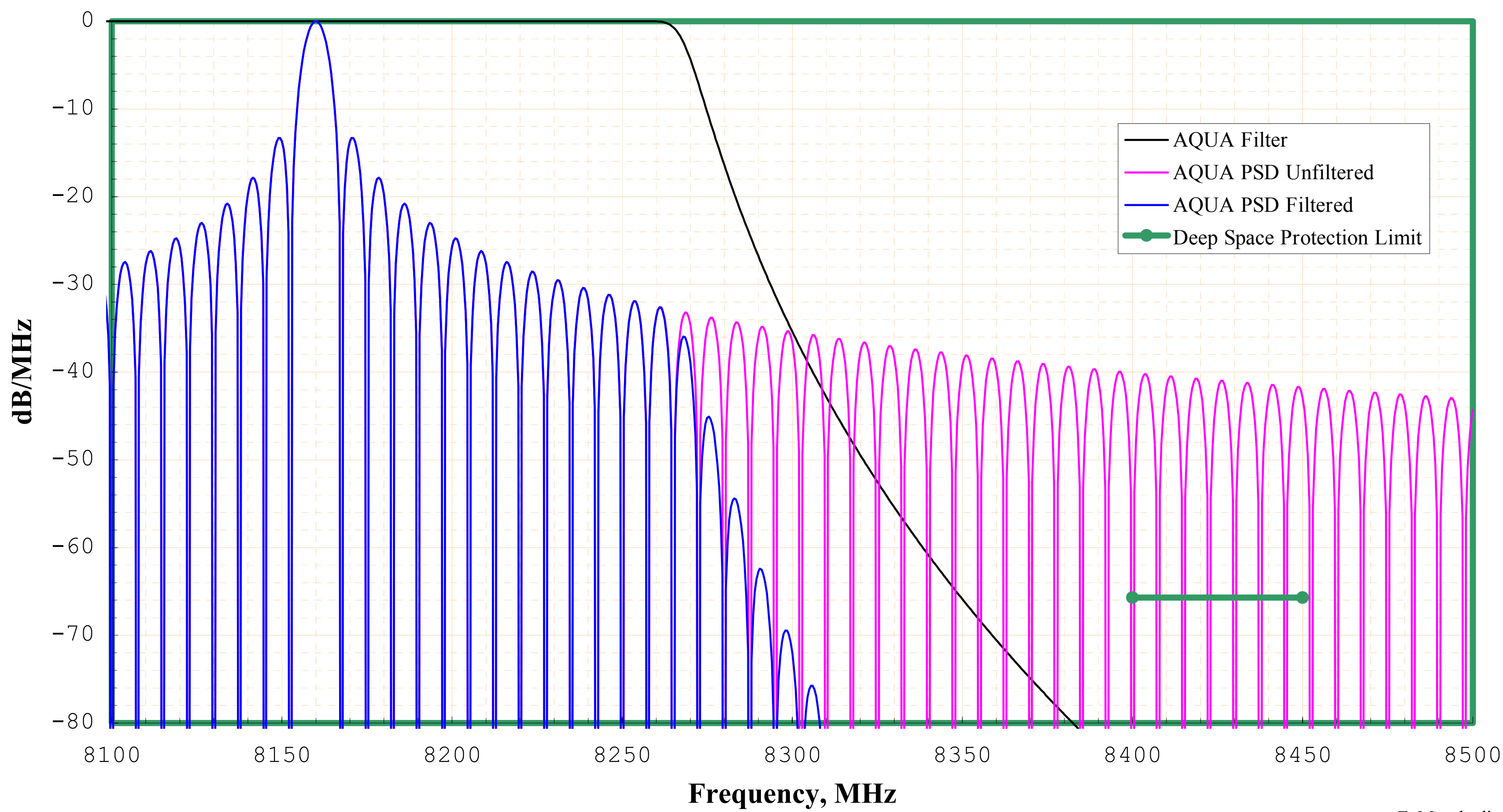


How Can EESS Missions Prevent Interference to The DSN?

AQUA Spectrum, with Filter for DSN

AQUA Direct Broadcast Mode

9-Pole Chebychev Filter, 15 Mbps QPSK Signal



The Lesson

- **It is very, very important to prevent interference at the source on board the satellite.**
  - **Otherwise the Project will lose time and freedom, and the Project and the DSN will pay the high price of operational coordination.**
  - **TERRA and DSN are currently experiencing the pain of coordination and implementation of a Waiver to their Operational Agreement for supporting the wild fires in Australia**

- **AQUA has demonstrated that utilization of a filter in the telecom subsystem is practical**
  - **Reduced cost of coordination and operations**
  - **Projects freedom to maximize utilization of the satellite**

A Pending NASA Directive to "Prevent RFI At The Source"

- **From the lesson of TERRA/DSN coordination NASA spectrum managers of Code M, Code Y, Code S, Glenn, Goddard, Johnson and JPL decided to propose a NASA directive with the following title:**

Preventing RFI at the Source

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A Guideline to NASA Earth-orbiting Missions
Transmitting in the 8-GHz
Earth Exploration Satellite Service (EESS) and
Space Research Service (SRS) Bands

The Pending Directive: NASA, considering

1. That its Earth-orbiting missions using the EESS band (8025-8400 MHz) and the upper SRS band (8450-8500 MHz) could cause adjacent-band interference to the lower SRS band reserved for deep space missions (8400-8450 MHz)

2. That radio frequency interference is prevented most effectively at the source, an approach which avoids the need for very expensive long-term operational coordination requiring planning, monitoring, analysis, and trouble shooting by highly skilled personnel,

The Pending Directive: NASA Directs

1. NASA's Earth-orbiting missions using the above-mentioned EESS and SRS bands to use proper modulation and/or filtering on board their spacecraft, as necessary, to avoid sideband emissions exceeding the protection criteria of the 8400-8450 MHz deep space band;

2. Such flight projects to address this issue explicitly in their project requirement and design documents, particularly in their Radio Frequency Interface Control Document, to review this situation in the early phases of their telecommunications design, and to send summaries of such reviews to their Center Spectrum Manager(s); and

The Pending Directive: NASA Directs (cont.)

3. Should the spacecraft hardware fail to deliver the clean spectrum as required and no hardware remedies are feasible, such flight projects are to immediately notify their Center Spectrum Manager(s) and their NASA Enterprise Spectrum Liaison and to seek coordination with the Deep Space Network. Such mandatory coordination shall be planned on non-interfering basis according to link analysis and in keeping with established practice, and it shall be documented in a Coordination Agreement between or among the affected parties. This Coordination Agreement should be approved by the appropriate Center Spectrum Managers and personnel from the affected projects, and concurred by the affected Enterprise Spectrum Liaisons, the NASA Spectrum Program Manager, and the NASA Spectrum Policy and Planning Officer.

Available Technical Solutions

- Sideband-limiting filters such as the high order Chebychev filter used by AQUA mission

- Bandwidth efficient modulations such as the GMSK and others recommended by CCSDS
  - CCSDS Rec. 2.4.17A, “Modulation methods for high symbol rate transmissions, space research, space-to-Earth, Category A”
  - The Space Frequency Coordination Group (SFCG) has also recommended spectrum masks for general efficiency of spectrum use by the Category A missions. (SFCG Rec. 21-2)

- The EESS Ka-Band (25.5-27 GHz) for higher date rates

Conclusion

- Operational coordination must be avoided or minimized.
  - It is increasingly important for NASA missions and networks to reduce labor intensive activities.
  - Operational coordination to avoid RFI is labor intensive and requires highly skilled professionals.
  - Necessity for coordination also impedes automation of spacecraft and network operations.
- RFI must be prevented at the source.
  - AQUA has proven that technical solution yields great operational payoff.
  - Bandwidth limiting filters and bandwidth efficient modulations are readily available.
- Higher data rates missions should use the EESS Ka-Band (25.5-27 GHz).